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War Department Technical Bulletin TB MED 164, dated June 1945, is reproduced for the information and guidance of all concerned:

MALARIA CONTROL IN THE ARMY

1. INTRODUCTION.

a. The control of malaria has presented one of the most important problems encountered by U.S. Army Forces operating in tropical and subtropical regions. Since a large proportion of the war effort is concentrated in such territory, proper realization of the malaria problem and thorough knowledge of the principles of its control are mandatory for all forces concerned. The control of malaria is not complex or unduly difficult. Only continuous and diligent application of a few basic principles are required to achieve satisfactory results.

b. Malaria is a communicable disease transmitted by mosquitoes belonging to the genus Anopheles. Control depends fundamentally on the prevention of bites by anopheline mosquitoes. A variety of means may be employed to attain this end. Among the most important are the elimination of mosquitoes by destroying their breeding places and by killing them with insecticides, and the interposition of barriers which will prevent them from biting troops. When complete protection against mosquitoes is not possible, certain drugs such as atabrine given regularly in small doses are highly valuable to prevent immediate sickness from malaria and thus to maintain the effectiveness of troops that may become infected.

c. The antimosquito measures employed to control malaria are, in general, also applicable to the prevention of other mosquito-borne diseases such as dengue and filariasis. This point should be stressed during the training and indoctrination of troops in malaria control.

2. RESPONSIBILITY.

a. The prevention of malaria is clearly designated by AR 40-205 and AR 40-210 as a function of command. Commanding officers are charged with the responsibility of the enforcement of regulations necessary for health within their command and with the correction of hazards that threaten the health of personnel of their command.

b. It is the function of medical officers to recommend to commanding officers the measures necessary to prevent disease, and to supervise those control measures that are undertaken. To discharge this function properly, medical officers must have a clear understanding of the principles of malaria control.

c. AR 100-80 charges the Corps of Engineers with the responsibility for sanitary measures necessary for the control of mosquitoes, including especially the filling and draining of breeding places and the screening of buildings.

d. To assist commanders in the discharge of their responsibility for malaria control and to augment the carrying out of mosquito control measures in oversea theaters, the Army has created a special organization for malaria control in the Medical Department (T/O & E 8-500). This organization consists of malaria control units (FA) and malaria survey units (FB). Malaria control units consist of 11 specially trained enlisted men who operate under the command of a sanitary engineer. They are trained and equipped to organize and supervise large scale mosquito control programs. Malaria survey units consist of 11 specially trained enlisted men and 2 officers of the Sanitary Corps, one an entomologist, and the other a parasitologist. They are trained and equipped to carry out entomological and parasitological surveys as they pertain to the control of malaria.

e. To provide for the necessary and all-important internal housekeeping malaria control operations, section IV, War Department Circular No. 117, 1945, requires that each company, battery, or similar unit will formulate an antimalaria detail consisting of a minimum of two enlisted men, including one non-commissioned officer. Such details carry out mosquito control measures in the unit area, maintain mosquitoproofing, and continuously inspect the organization for breaches of malaria discipline. In certain larger units, such as corps, divisions, and battalions, the appointment of a specially designated malaria control officer has proved advantageous in assisting the commanding officer in carrying out his responsibility in regard to malaria control.

3. MALARIA DISCIPLINE

a. There is only one general measure of malaria control applicable to all situations and to all individuals. This approach

to malaria prevention is best described by the term malaria discipline. Malaria discipline implies the full and willing cooperation of personnel of all ranks in faithfully and continuously observing personal protective measures. Without good malaria discipline, all other control measures fall short. All control programs must begin with and must continuously emphasize this aspect.

b. Personal protective measures are defined as those that the individual himself must apply. They may be enumerated as follows:

(1) Bed nets. Nets to protect sleeping individuals are very useful in preventing malaria because anopheline mosquitoes usually bite at night and can bite more easily when a man is asleep and motionless. To be effective, however, they must be properly employed and properly maintained. The lower edge must be so tucked in that no opening is available for mosquitoes to enter. Overhead frames should be provided for bed and cot nets. These should not have sharp points which will catch and tear the netting. Nets used in small tents should be suspended from and conform to the shape of the interior of the tent. Shelter tent nets should not be used over the outside of the tents, but hung inside. Nets should be folded up by day. Before the net is entered at night, the interior should be sprayed with insecticide to kill stray mosquitoes. Bed nets may have their effectiveness increased by impregnation with repellent as mentioned in (3) (b) below.

(a) It is highly important that nets be available for use from the first night spent in malarious areas. There are places in the Tropics where a single night of exposure to mosquito bites may result in a 20 percent or greater infection rate among the exposed troops. Nets should therefore be carried as items of personal equipment by all personnel proceeding to malarious zones and should be immediately available upon arrival. Even in the forward areas it is highly important to utilize this protective measure whenever feasible.

(b) Repair of holes and tears should be prompt and complete. Adhesive tape, sewing, or patching may be used to repair rents in the netting. Frequent inspection should be made to insure that nets are properly used and are maintained in good condition.

(2) Protective clothing. Except when in bed and suitably protected by a bed net, individuals must wear long trousers and long sleeve shirts buttoned to the neck with sleeves rolled down from dusk until dawn. Trouser legs should be encased in leggings or boots. High shoes must be worn, or where available, mosquito boots or jungle boots should be employed. Head nets and mosquito gloves, procurable from the quartermaster, offer a useful adjunct, but their use in the heat of the Tropics or under combat

conditions may be attended with such additional discomfort and impairment of vision as to make their use extremely unpleasant or even undesirable.

(3) Chemical repellents. The quartermaster issues an excellent insect repellent (QM Stock No. 51-R-265), better than any heretofore available, which usually gives good protection for at least 2 hours, even under sweating conditions. This agent, supplied in 2-ounce bottles, is practically odorless and nongreasy, and, if properly applied, produces no unpleasant effect upon the user.

(a) Repellent should be carefully applied over all exposed surfaces of the body (except the lips and eyes), and to clothing where it is stretched tightly over the body, as over the shoulders, buttocks, and ankles. Application to the skin should be repeated every 2 hours following the initial application at dusk and until the individual retires under a mosquito bar for the night.

(b) Repellents are also useful for the impregnation of bed nets to keep mosquitoes from biting through if the body should accidentally come in contact with the net while sleeping. The netting may be wadded together and repellent thoroughly rubbed into the material by hand. Effectiveness will be retained for several days or longer.

(c) Precautions must be observed in the use of repellents to prevent contact with plastics. Repellents in current use are plastic solvents, and are capable of damaging fountain pens, plastic watch crystals, plastic water bottles, etc.

(4) Suppressive medication.

(a) Certain drugs, such as atabrine or quinine, taken regularly in proper doses will prevent sickness from malaria even though men are bitten by infected mosquitoes. These drugs do not prevent the infection. They merely postpone illness which might be incapacitating at an inconvenient time. Most men who have been infected with Plasmodium vivax will eventually suffer an attack of malaria, usually within 1 or 2 months, after the suppressive drug is stopped. Drug suppression of malaria is fully discussed in TB MED 65, 3 July 1944.

(b) Use of suppressive drugs is a highly valuable means of maintaining the health of men who must operate in malarious regions where full protection against mosquitoes cannot be given. When troops become heavily seeded with malaria it may be necessary to continue suppressive medication even though no further exposure to the disease is occurring. Otherwise, relapses may be so numerous as to interfere with the military effectiveness of the unit. Experience during this war has demonstrated conclusively that, when atabrine is taken regularly, noneffectiveness from malaria can be

kept at a satisfactorily low level, even under conditions of combat.

(c) For suppressive medication to be effective, it is essential that the drug be taken regularly in the prescribed amounts. Men should be carefully indoctrinated in the principles of this approach to malaria control. The drug should be administered by roster at mealtime under the supervision of an officer who must make certain that the tablets are actually swallowed. Any individuals failing to take the drug at the regular time should be required at subsequent musters to take an extra tablet until the amount missed has been made up. Also, men on detached duty should be given sufficient drug for the period they are to be away, with specific directions for taking it. If an appreciable number of cases of malaria occur in a unit taking suppressive medication, it is prima facie evidence that discipline in taking the drug is poor, and is a reflection upon the efficiency of the commanding officer concerned.

(d) It should be emphasized that the taking of suppressive medication is not a true malaria preventive measure but is merely a means of avoiding the occurrence of symptoms at an inconvenient time. Consequently, mosquito control operations and individual protective measures should be pressed vigorously even though a suppressive drug is being taken. If the risk of infection is sufficiently great to necessitate the use of suppressive treatment, it is all the more important to stress precautions against mosquitoes.

(5) Avoidance of unnecessary exposure.

(a) In some places, a high percentage of all malaria infection is acquired while soldiers are visiting unprotected towns or villages after dark. Such places should be declared out of bounds, or the usual leave hours should be changed so that passes require the soldier to return to the protected camp before nightfall. Beneficial results will be obtained in venereal disease rates as well as in malaria incidence. When men are restricted to camp in the evenings, additional efforts to provide recreation and entertainment will be required, lest the morale of the command deteriorate.

(b) Swimming and bathing out of doors after sundown should be prohibited in areas where there is risk from malaria-carrying mosquitoes.

(c) Showing of motion pictures out of doors constitutes an important malaria hazard because men are congregated at a time when anopheline mosquitoes are most active. Properly screened buildings for motion picture shows should be provided in malarious areas as far as possible. When this is not feasible, mosquito control measures in and immediately around the unit area should be applied before the use of an outdoor or unscreened theater is permitted. The site of an open air theater and a zone at least 50 feet beyond the seating area should be cleared of trees and brush and the

grass should be cut short. The area should be sprayed with insecticide before each performance, particular care being taken to spray under all benches and seats. The wearing of protective clothing and the use of repellent should be strictly enforced.

c. Means of attaining malaria discipline.

(1) Education. All officers and enlisted men should be thoroughly indoctrinated with the facts concerning malaria and with measures necessary for its control. Section IV, War Department Circular No. 117, 1945, prescribes that all components of the Army shall receive a course covering the various aspects of malaria prevention. A minimum of four 1-hour lectures is directed, and Training Circular No. 16, 1945, serves as a guide to such instruction. Additional refresher instruction should be given at frequent intervals to maintain a high degree of awareness to the problem. The following aids to instruction are available:

FM 21-10--Military Sanitation and First Aid.
TF 8-953--Malaria--Cause and Control.
TF 1-3343--Malaria Discipline.
Film Bulletin No. 200--Malaria Control on Corsica.
Miscellaneous Film No. 1035--Silent Battle.
Graphic Training Aid 8-4--Graphic Portfolio on Malaria.
FS 8-12--Control of Insect-borne Diseases.
MTP 8-2--Mobilization Training Program for Medical Units of the Army Service Forces.

(2) Propaganda. Lectures or warnings repeated too frequently become wearisome, and may eventually defeat the purpose in view. To prevent this, varied use should be made of different outlets such as poster contests, posters, movie shorts, radio broadcasts, and organizational newspapers.

(3) Inspection. Thoroughness in the use of personal protective measures varies directly with the amount of inspection carried out. Frequent visits and inspections should be made within organizations to impress individuals with the importance of their compliance and to determine where disciplinary action is necessary. Full use should be made of military police to insure correct wearing of the prescribed uniform, that individuals leaving camp at night carry a bottle of repellent, that repellent is used at outdoor evening gatherings, and that out of bounds or restricted zones are not visited.

(4) Disciplinary action. Commanding officers are responsible for compliance of their troops with local regulations governing malaria discipline. Appropriate disciplinary action should be taken against those individuals who disregard orders concerning

protective clothing, suppressive atabrine, use of bed nets, or who commit other infractions of malaria discipline.

4. ENVIRONMENTAL MEASURES APPLICABLE TO FIXED OR SEMIFIXED INSTALLATIONS.

a. General. Environmental control measures include procedures such as mosquitoproofing of buildings, draining and filling of mosquito breeding places, spraying and larviciding, all of which have their greatest usefulness at permanent bases and semifixed installations. These measures should also be applied in forward positions as soon as the military situation permits. From 4 to 6 weeks must elapse before measures to control mosquito breeding will materially reduce the hazard of malaria transmission. On the other hand, mosquitoproofing, and especially spray killing, of adult mosquitoes are immediately effective in this respect. Environmental control measures for a large base or area are most efficiently carried out when coordinated in a planned malaria control program supervised by centralized authority.

b. Proper selection of camps. The selection of a suitable camp site is an important antimalaria measure. A native village in which there are numerous infected persons is a health hazard to troops in a camp within flight distance of the malaria-carrying mosquito. So, too, a large breeding place of these mosquitoes, if located within easy flying distance of a camp, is a menace. The effective flying range of malaria mosquitoes rarely exceeds a mile in the Tropics but is apt to be more than this in temperate zones, or under exceptional conditions of wind or terrain in the Tropics. If the military situation permits, camps should never be located nearer than a mile from malarious villages or important breeding places of malaria mosquitoes. If this cannot be avoided, it is helpful to locate the camp to the windward of these places. The importance of a breeding place depends not on its appearance or altogether on its size but on the malaria-carrying capacity of the mosquitoes breeding in it. It is equally important, where feasible, not to allow natives to live on a military reservation or within a mile of military quarters, for they will provide a reservoir of infection. If such natives are employed as laborers they should not be permitted on the reservation between sundown and sunrise.

c. Mosquitoproofing of buildings. This is one of the most effective measures in reducing malaria. Not only sleeping quarters but also washrooms, latrines, mess halls, day rooms, post exchanges, theaters, and all other buildings where personnel may congregate indoors during the evening should be mosquitoproofed. In so doing, every effort should be made to interfere with ventilation as little as possible. The following methods of mosquitoproofing should be utilized:

(1) Screening of windows and doors. Certain general principles should be observed if screening is to give its full value as an antimalaria measure.

(a) Suitable weather-resistant wire of proper mesh should be used. It is universally desirable, and in some areas mandatory, that the mesh should have at least 18 wires per inch. Where wire screening is not available, plastic screening material or even cotton bobbinet similar to that found in the standard issue mosquito bar, may be used.

(b) The screening should be so applied that breakage during use will be minimal and that the doors will not facilitate mosquito passage. For instance, screen doors should open outward, and should be on the windward side of a building; if possible. They should be strongly constructed so that they will not sag or warp. They require springs or other devices so that they will close automatically. Strips of discarded inner tubing, and weights on pulleys, make excellent door closers. The places where a foot or hand would naturally be applied to open a screen door should be protected with a cross strip of wood or metal. Screen doors should shut against strips of wood or metal so as to block entry of mosquitoes through the space between door frame and door. In highly malarious areas it is desirable to have double screen door barriers with a vestibule at least 6 feet in length between them.

(2) Careful attention must be paid to the closing of all possible apertures not screened, such as cracks and knotholes, spaces where floor or wallboards have separated, openings between flooring and walls, corner openings where joists come together, holes where window shutter prop sticks extend into a room for easy handling, ventilating pipes and shafts, etc. This may be attained by completely lining the walls and ceilings with building paper, hessian cloth, or burlap. This is particularly applicable to native type buildings constructed of bamboo. Holes may be covered with tin shingles or pieces cut from ordinary tin cans. Window braces can operate through slits in pieces of inner tubing without admitting mosquitoes. A filler for holes, cracks and spaces under corrugated sheet metal roofing, may be made by boiling shredded paper and flour into a fairly homogeneous mass and then adding sand and cement to form a plastic which may be moulded into the holes. This filler is somewhat pliable and will retain its place fairly well. Oakum, Spanish moss, or similar materials may be used for the same purpose.

(3) Tents can and should be mosquitoproofed. The method employed will depend upon the type of supplies available, and should be adapted to meet local conditions. Mosquitoproofing is most satisfactorily attained where a wooden frame is constructed upon which the standard issue pyramidal tent may be suspended. Plastic or

cotton bobbinet mesh may be stretched from one brace to another so as to form a complete liner. When available, a strip of hessian cloth 1 foot wide should be sewn to the bottom of this liner so that it may be tucked beneath the floor boards. Where tent frames are not available, excellent mosquitoproofing may be obtained by loosely sewing the same material to the edges of the pyramidal top, allowing it to drop down and form an effective liner for the side walls. When this method is used, mosquito netting should be employed to screen the air vent at the top. Entrances should be screened with two layers of netting suspended from the top, with one layer sewn to the side wall on one side, while the other layer is sewn to the side wall on the opposite side. The free edge of each layer should be stabilized by weighting the free bottom corner with a stone. Building paper is excellent for mosquitoproofing the wooden side walls of "winterized" tents. Wooden floors can be made insect proof by laying them double, with building paper between the two layers.

(4) Proper routine maintenance of screening is essential, with prompt and effective repair of rents and tears and discovery and blocking of new cracks and knotholes. The importance of these apertures for mosquitoes is out of proportion to their seeming insignificance. Soldiers who occupy hutments and barracks should be taught to make all minor repairs. Strict supervision of screening is essential. It is desirable to assign an enlisted man from the unit antimalaria detail as mosquitoproofing maintenance orderly, with duties to inspect all screening at regular intervals, making such repairs as are within his capabilities and reporting others to proper authorities.

d. Destruction of adult mosquitoes. One of the most effective means of breaking up the cycle of malaria transmission is the destruction of the adult mosquito. The Army has adopted two agents which are the best weapons yet found for this mode of attack. These insecticides, 5 percent DDT dissolved in kerosene used as a residual spray (QM Stock 51-I-305), and pyrethrum-DDT solutions as issued in the aerosol insecticide dispenser (QM Stock 51-I-159), have different modes of action, and, to obtain the maximum results, they should be used in conjunction with each other. When aerosol dispensers are not available, liquid finished spray (QM Stock 51-I-169) dispensed from flit-gun type sprayers should be used to kill adult mosquitoes inside buildings. In malaria seasons it is essential to apply residual spray to all types of mosquito resting places. Such spraying should include native villages within a radius of a mile. Shelters may include not only barracks, mess halls, day rooms, and tents, but also latrines, storehouses, stables, culverts, tree holes, etc., depending upon the habits of the species involved. If troops are operating in hostile areas, local villagers may abandon their homes, leaving behind infective mosquitoes. It is especially important to spray such villages as soon as possible after they are occupied.

(1) DDT residual spray. The use of DDT in a 5 percent solution in kerosene as a residual spray is fully discussed in TB MED 110, 25 October 1944.

(a) In many malarious areas, vector mosquitoes will be found resting indoors during daylight hours. In such instances marked destruction of infected mosquitoes may be achieved and the total mosquito population may even be reduced by widespread application of DDT residual spray. All mosquito resting places, such as ceilings, walls, closets, under surfaces of beds, tables, chairs, and bed nets should be treated. The spray should be applied evenly to the point of wetness with a flit-gun or knapsack sprayer in doses up to 200 mgm per square foot (1 quart of 5 percent solution per 250 square feet). Native dwellings in controlled areas, cowsheds, day rooms, latrines, mess halls, barracks, and other buildings should be sprayed. Where carefully applied, the residual effect persists up to 3 months. Where the item, insecticide, DDT, residual spray, is not available, a suitable preparation may be obtained by dissolving 7½ ounces of Larvicide, DDT, powder, dissolving (QM Stock No. 51-L-120) in each gallon of kerosene.

(b) Where the vector species prefers sylvatic resting places, area spraying of vegetation and tree holes may be expected to yield similarly good results. Barrier zones may be established around bivouac areas, isolated observation posts, gun emplacements, and outdoor gathering places such as open air theaters, by spraying vegetation within a radius extending at least 10 yards beyond the boundary of the area to be protected. A 5 percent solution of DDT should be sprayed at waist height using a power sprayer, knapsack sprayer, or hand sprayer. Application should be in dosages up to 5 gallons per acre. Under favorable conditions this treatment will yield residual effects for from several days to a week.

(c) The use of DDT as a residual spray for the destruction of mosquito adults is considered to be the most effective application of this agent in malaria control. Its use in this respect should be given high priority. Since DDT does not give an immediate knockdown, its use in dwellings where troops are quartered must be supplemented by spraying with the aerosol dispenser or with liquid finished spray which have a more rapidly toxic effect. The warning that DDT is not a panacea in insect control is repeated. DDT is only an additional weapon. Its use must be attended by the application of all other control measures with continued vigor.

(2) Aerosol insecticide dispenser.

(a) A handy self-discharging aerosol dispenser, commonly referred to as a "mosquito bomb"; has proved highly valuable to troops against adult mosquitoes in malarious areas. The

item, Insecticide, aerosol, 1-pound dispenser (QM Stock No. 51-I-159), is issued in the form of a small steel cylinder under pressure, equipped with a release valve. The aerosol insecticide formula has been altered recently to include DDT in order to increase its effectiveness. The new formula consists of 3 percent DDT, 2 percent pyrethrum extract (containing 20 percent pyrethrins), 5 percent cyclohexanone, 5 percent hydrocarbon oil, and 85 percent Freon-12. The freon is nontoxic to man and is noninflammable. It is used as an expellent to dispense the other ingredients. Dispensers containing the new formula may be identified by the label and the olive drab color, in contrast to the black color of those remaining in stock which contain pyrethrum but no DDT.

(b) The dispenser is useful for spraying all types of enclosures, such as barracks, billets, tents, bomb shelters, trenches, fox holes, jungle shelters, mosquito bars, jungle hammocks, and gun emplacements, as well as aircraft and ships. Forward areas should be supplied with the dispensers in preference to rear bases where other mosquito control measures can be employed. The insecticide is released in very small particles (aerosol) which pervade the atmosphere. In contrast to ordinary sprays, the aerosol remains suspended in still air for 2 or more hours, thus giving continued protection against insects entering the enclosure for some time after the application, in addition to killing those present at the time of spraying.

(c) A closed pyramidal tent requires only 10 seconds spraying, and 3 seconds are sufficient for a pup tent. Four seconds spraying is adequate for each 1,000 cubic feet (10 x 10 x 10). The aerosol should be dispensed only for the time indicated. Wastage due to overdosage is a common error. To spray a room or hutment, the container is carried rapidly about the inclosure while the aerosol is allowed to discharge. No direct hits on the insects should be attempted, as this wastes insecticide. Although regular use of the DDT-pyrethrum aerosol may gradually build up a toxic residue on the walls and objects on which it is deposited, the residual type spray should be applied when control by a residual effect is desired.

(3) All spraying operations for residual effect should be carried out by trained personnel under the direction of a centralized authority. This is necessary in order to assure proper application of the spray and repetition of the treatment at proper intervals. Routine insecticidal spraying within unit areas, however, may be performed by unit malaria control details. Small cages of adult mosquitoes may occasionally be concealed in unit barracks or hutments to check the efficiency of spraying details.

c. Control of mosquito breeding.

(1) Drainage. It is highly important that fixed

installations have suitable antimosquito drainage integrated with the usual system of drains designed to carry the normal surface water runoff. This coordination is particularly necessary in road construction. The following rules in setting up a drainage program are standard.

(a) Drainage should be undertaken early, during the actual construction period. It is desirable to have it well in hand before the camp or station is occupied. It is also important to avoid blocking an existing drainage system by new construction. Construction activities, as far as possible, should be planned and controlled to prevent creation of excessive new mosquito breeding places.

(b) No drainage scheme should be undertaken without careful preliminary surveying and planning, and, to this end, personnel trained in malaria control should be placed in charge of the work. Drainage to control mosquitoes may be accomplished by the use of surface ditches, subsurface drains, vertical drains, pumps, tide gates, and other devices. In every case the aim is to drain an area in such a way that, regardless of weather or tide, there will be no mosquito breeding.

(c) Drains should be as few as will accomplish the purpose. Most drainage requires that levels be run, and that well-thought-out plans be made as to the relation of a drainage system to existing water supplies, to other sanitary improvements, to disposal of sewage, and to the maximum amount of water to be carried in the rainiest season. In some areas where the vector breeds in seepage or in slowly running water, open ditches may cause a greater malaria nuisance than the area they drain.

(d) Where a satisfactory outlet is not available, land may sometimes be graded so that surface water accumulates in one or more pools which can be periodically treated with larvicides.

(e) Ditch maintenance is a very important item for which adequate provision must be made.

(2) Filling. It is usually necessary to do a considerable amount of filling on the site of a new permanent installation. Special attention should be given to the elimination of man-made depressions under buildings, beside roadways, and in other places where earth has been borrowed for various purposes. In some areas, the most potent vector species will be found breeding prolifically in such places and in small collections of water in hoof prints, road ruts, shell holes, and bomb craters. Permanent control may be obtained where filling of such impoundments is possible. Disc harrows are useful to eliminate road ruts and hoof prints.

(3) Stream clearance. The breeding of mosquitoes in marginal pools and collections of flotage in otherwise freely running streams and canals often requires considerable attention. In such situations, stream margins should be straightened and cleaned of vegetation. Marginal pools may be filled, or may be drained, by connecting them with the main stream. Surface obstructions tending to collect flotage should be removed and frequent attention should be given to maintain the stream as free from mosquito breeding places as possible.

(4) Larvicides. Larvicides are substances used to kill mosquito larvae in breeding areas which it is not feasible to drain or fill. To be effective in controlling mosquito breeding, larvicides must be reapplied at intervals of from a week to 10 days. Diligence in completely covering the water surface is required. Three main groups of larvicides are available and are discussed below.

(a) The use of DDT as a 5 percent solution in oil or as a 10 percent dust for larvicidal purposes is described in TB MED 14, 3 March 1944.

1. Solutions prepared by dissolving (QM Stock No. 51-L-120) in oil may be applied to water surfaces by hand sprayer, knapsack sprayer, powder sprayer, or by merely pouring it on the surface. Dosage of 2 quarts (0.2 pound of DDT) per acre of water surface is adequate in most situations to kill 90 to 100 percent of larvae. In order to obtain complete coverage it is often advantageous to use equivalent amounts of DDT in more dilute solution (1 or 2 percent). This is particularly true when spreading properties are diminished in the presence of an algal scum or heavy growth of surface vegetation. Under ideal circumstances larger doses of DDT up to 5 pounds per acre may give residual effects up to 3 weeks. This dosage is not recommended, however, where wind, rain, or other inclement circumstances are apt to break up or remove the surface film. Dosages of DDT greater than 0.2 pound per acre may kill fish and be harmful to wild life.

2. The DDT dust preparation (Larvicide, DDT powder, dusting (QM Stock No. 51-L-122), should be diluted with four to nine parts of any dry dust diluent for application with a hand rotary duster (Duster, insect, hand, rotary blower type, paris green or powder, 5- to 10-pound capacity; Engineer Stock No. 41-3115.5-10) at the rate of 0.1 pound of DDT per acre. The stock dust is 10 percent micronized DDT in talc. When the dust is distributed by handcasting, the stock dust should be mixed with 50 parts of diluent in order to make it easier to maintain a rate of distribution of 0.1 pound of DDT per acre. A more complete description of dusting methods is given under paris green in (4) below. In general, oil solutions are more satisfactory for routine use than

dust preparations.

(b) Petroleum products.

1. Suitable oils such as Diesel oil or fuel oil No. 2, properly applied, will kill the aquatic stages of all species of mosquitoes and will also destroy sheltering vegetation at the edges of breeding places. The chief killing factor is a toxic action following contact with the tracheal cells of larvae and pupae.

2. Kerosene or gasoline may be used as larvicides and will give a good kill but they form transitory films, are expensive, and may constitute a fire hazard. Occasionally it may be desirable to kill larvae in a well by a film of gasoline, which soon evaporates, leaving no taste in the water. Leaded gasoline should not be used on drinking water.

3. Waste motor oils are not highly toxic to larvae because they are relatively nonvolatile. However, they may be used effectively when 5 percent DDT is added.

(c) Application of oil and DDT oil solutions. The following methods may be employed in using oil preparations as larvicides:

1. Sprayers. The knapsack sprayer consists of oil container, hand pump, and spray nozzle, and is carried and operated by one man. The ordinary sprayer has a capacity of from 3 to 5 gallons and a spraying range of about 25 feet. The knapsack sprayer (Sprayer, insect, knapsack type, plunger type, cylindrical shape, 3-gallon capacity, Engineer Stock No. 41-7839.400.030) is a practical and economical apparatus for applying oil to ditches, small ponds, or other collections of water which can be reached by the spray. Large power sprayers (Sprayer, insect, portable, piston pump type, gasoline engine driven, skid mounted; Engineer Stock No. 40-9030.6-3) may be employed to oil extensive areas such as the borders of lakes, or in some instances, swamps. A fog type of spray is required when DDT oil solution is dispensed, utilizing wind currents to distribute the material. Continuous action flit-gun sprayers (Ql Stock No. 41-S-4106) are suitable for this purpose.

2. Airplane spraying. For large scale area control, specially equipped aircraft may be employed to spray oil solutions of DDT. Application at the rate of from 0.2 to 0.4 pound of DDT per acre will give good kill of adult mosquitoes in addition to the larvicide effect. Various types of equipment and aircraft have been used in the field. The slipstream of the airplane is utilized to break up the spray material into small-sized particles

which can penetrate covering vegetation. Airplane spraying is most useful in battle zones where the military situation precludes standard methods of mosquito control. It is also advantageous for treatment of large inaccessible areas. Spraying operations should be carried out by specially trained pilots and coordinated with malaria control measures on the ground. In agricultural regions, possible harmful effects of DDT on plants and beneficial insects may be important and must be considered.

3. Continuous oilers. Continuous oilers are useful where the oil will be dispersed by currents, as in streams or ditches. It must be pointed out that continuous oilers require a good deal of attention, generally use more oil than would be dispensed for the same area from a knapsack sprayer, and often are unreliable. They should not be used unless other methods are found impractical. When DDT solutions are employed, less oil is required. Three types of continuous oilers are described below:

(a) Drip oilers consist of a tin or drum of about 5-gallon capacity, placed on supports over a stream or ditch so that oil will drip on the water surface. The size of the hole will govern the amount of oil dropping from the container. In homemade containers, a nail hole may be used with a nail left loosely in the hole. It may be necessary to use some string to form a washer around the nail head. The can should be several feet higher than the stream surface, so that oil will spread quickly when drops strike the water. More refined modifications of this type of oiler can be improvised.

(b) Submerged oilers are containers having two small openings. They are designed so that when sunk to the bottom of a stream or pond their oil will escape through one opening and be replaced by water which enters through the other. These cans have the disadvantage that they are difficult to adjust so that oil will flow properly, as the openings are easily clogged.

(c) Oil solutions of DDT may be applied continuously by means of a weighted submerged bag of sawdust or coconut husks soaked with the solution. Also, balls prepared by mixing two parts of sawdust, one part of plaster of paris and one part of water may be soaked with 5 percent DDT oil solution and dropped into small permanent collections of water.

4. Amounts of oil required. Using Diesel oil No. 2, from 10 to 30 gallons are required per acre of water surface for complete coverage with a uniform, stable oil film. When 5 percent DDT in oil is used, only 1 or 2 quarts per acre are required. With an ordinary knapsack sprayer, one laborer can oil about 2 or 3

acres of breeding area per day if the terrain is not difficult. It is usually necessary to spread oil once a week.

5. Precautions in using DDT. DDT in oil solution is absorbed through the skin and may cause toxic effects. Occasional contact with oil solutions is apparently not harmful, but repeated or prolonged exposure should be avoided. Clothing contaminated with DDT solutions should be removed as soon as possible and the skin bathed with soap and water. Sprayers should be checked frequently to prevent leakage. DDT is poisonous if ingested and consequently must never be stored with foodstuffs.

(d) Paris green. Paris green (an acetoarsenite of copper) properly applied is a highly effective anopheline larvicide. Although the specific gravity of paris green is greater than that of water, it usually remains on the surface for at least several hours. The longer it floats the better it is as an anopheline larvicide. The usefulness of paris green depends on the fact that it kills larvae when ingested. It is particularly effective against Anopheles larvae, which feed at the surface. It is less effective against Aedes and some Culex larvae, which feed only part of the time at the surface. As ordinarily used for mosquito control, it is harmless to man, animals, fishes, and aquatic vegetation. It is frequently the larvicide of choice for the treatment of rice fields where oil solutions might injure the plants.

1. Dust dilutions of paris green. Dust mixtures are prepared with diluents such as powdered soapstone, slaked lime, or road dust. The diluent must be well mixed with paris green, the required dilution varying from 5 to 10 percent by volume for hand-operated blowers (Duster, insect, hand, rotary blower type, paris green or powder, 5- to 10-pound capacity; Engineer Stock No. 41-3115.5--10) and from 1 to 2 percent for handcasting. When dusted from airplanes, 25 percent mixtures are usually employed.

2. Method of dust distribution. Paris green mixtures can be applied to ponds, lakes, and larger streams with rotary dust blowers by putting the dust into the air from the windward side so that it will form a cloud and be carried out over the water. For large bodies of water, a slowly setting dust cloud carried along by a light wind will give best results. Paris green is heavier and falls faster than its diluents. A good working rule is to assume that larvicidal quantities of paris green will be carried only half the distance traversed by the visible cloud. Generally, the best results will be obtained on a sunny day after the dew has evaporated from the vegetation. In the case of small bodies of water where vegetation is heavy or where ditches and streams are too narrow to be dusted by the cloud method, handfuls of dust mixture

should be thrown directly on or into the vegetation or onto the surface of the water. Airplanes may be used to apply the dust over large areas such as extensive swamps. Airplane dusting should be done in the early morning or late afternoon when winds are low and when convection currents over the water are least troublesome.

3. Amount of larvicide required. The amount of larvicide required to treat an area of given size will vary according to the amount of vegetation present, greater quantities being used where grass, reeds, or other plants are present. From 1 to 3 pounds of paris green are generally required per acre of water surface. Under average conditions paris green should be applied at intervals of from 6 to 7 days. One man can usually prepare and spread paris green mixtures along about 1½ miles of bank in 1 day, depending on local conditions.

4. Dustless application of paris green. When the preparation or transportation of dust diluents is not feasible, an alternate method of application may be employed. Paris green may be mixed with wet sand or small pebbles and distributed by hand. Or, a stock suspension may be prepared from the following materials: Kerosene oil--1 pint, paris green--½ pint, egg albumen (dry powdered), ¼ teaspoonful. If powdered egg albumen is not available, an albumen solution can be prepared by using from four to six egg whites in a pint of water. Use one-fourth of a pint of this solution to 1 pint of kerosene. The egg albumen is not absolutely essential but it tends to make the paris green more evenly distributed in the final spray. To prepare the final spray, 25 cc of stock suspension is mixed with 5 quarts of water in a knapsack sprayer. The labor of transportation is reduced if the mixing is done at the breeding place to be sprayed. Frequent agitation is required to keep the spray well mixed while it is being applied from the sprayer.

(c) Care of equipment. Equipment for spreading oil, DDT, or paris green larvicides requires careful maintenance. It should be overhauled and thoroughly cleaned at frequent intervals. Full sets of replacement parts should be stocked.

(5) Miscellaneous measures to deal with breeding places. (a) In some areas, streambreeding anopheline vectors may be controlled by periodically sluicing the stream. A small dam is built to impound water which can be suddenly released to flush away the larvae.

(b) Where irrigation water in rice fields or canals is a source of breeding, effective mosquito control is sometimes possible by interrupting the supply of water so that the fields become just dry enough each week to remove the surface film of moisture without drying the roots of the plants. In general, however, all wet cul-

tivation such as sugar cane or rice within 2 miles of any fixed Army installation is undesirable and should be eliminated, if feasible.

(c) Periodic fluctuation of water level in ponds and reservoirs is sometimes very effective in controlling mosquito breeding by preventing growth of shore line vegetation favorable to the larvae.

(d) In some areas routine attention must be paid to artificial breeding places such as wells, cisterns, roof gutters, and various types of household water containers, tin cans, and coconut shells. These may be screened, emptied, oiled, or destroyed, as indicated. In wells and in pools without much vegetation, some help in larval control may be had by using larva-eating fishes, such as Gambusia affinis.

5. ANTIMALARIA SUPPLIES. The procurement and distribution of antimalaria supplies are of the utmost importance in establishing early effective malaria control. Commanding officers of all echelons in malarious areas must pay the strictest regard to these items in all logistical considerations. Paragraph 7, Section IV, War Department, Circular No. 117, 1945, specifically directs that antimalaria supplies will be given highest priorities of movement to, and especially within, malarious theaters. Allowances of antimalaria supplies for various geographical areas are published in ASF Catalog QM 4, January 1945.

6. MALARIA CONTROL UNDER COMBAT CONDITIONS.

a. General. As in all other aspects of field operations, discipline is the mainstay of malaria control under combat conditions. Without malaria discipline in the field of combat, fighting forces can be and have been decimated by malaria in a month. The malaria rate of an organization is a good index of the efficiency of its command. Malaria control is never automatic. It requires unremitting attention to detail. In field operations, troops must be indoctrinated to the point where personal protective measures are a matter of unthinking habit, for at such times more than any other a man's health becomes his own responsibility. Sickness of an individual not only impairs fighting efficiency of the unit, but also is a handicap to survival of that individual when in contact with the enemy. The following measures must receive the strictest attention.

b. Selection of camp sites. The fact that the enemy must be dealt with at the point where contact is made is fully recognized, but where troops are on the march every effort must be made to select sites for bivouac as outlined in paragraph 4 b.

c. Protective clothing. Troops must avail themselves of

the full protection provided by the prescribed uniform regulations. Heat, rain, and other environmental circumstances must not be allowed to interfere with full employment of this essential protective measure.

d. Repellents. Commanding officers should procure and issue repellents to their troops in the required amounts. Every effort must be made to insure its faithful utilization on the part of combat forces. The use of protective clothing and repellents is the keynote of malaria prevention under field conditions.

e. Nets. The difficulty in transporting bed nets or jungle hammocks under operational circumstances is recognized. These protective aids, however, should be constantly available for issue to troops when the tactical situation permits, especially in rest areas behind the front lines. The use of head nets and mosquito gloves is a helpful adjunct to malaria prevention when circumstances permit their employment. Used in conjunction with proper clothing, they afford protection for men who must sleep in forward areas without bed nets or jungle hammocks.

f. Suppressive drugs. When prescribed by appropriate authority, suppressive medication should be given by roster under the supervision of an officer wherever possible. If this is not practicable in forward areas, troops should be supplied with sufficient drug for self-medication during the period of action, and given explicit directions for taking it. If the drug is regularly taken, sickness from malaria will be prevented and combat effectiveness will be maintained even in highly malarious areas.

By order of the Chief Surgeon:

H. W. DOAN,
Colonel, Medical Corps,
Executive Officer.